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Climate Change Information and Potato Production in Ebonyi State, Nigeria

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ABSTRACT

The study examined climate change information and potato production in Ebonyi State, Nigeria. About 96 potato farmers were selected using a purposive method. Primary information on the objectives of the study was collected with questionnaire and analysed using percentages, charts, and the probit regression model. The results show that potato farmers were of a productive age, married, experienced, and relatively educated. Most of the potato growers (90.6%) were highly aware of the changing climate disturbance. Radio (97.9%), fellow farmers (98.9%), workshops/training (91.7%), and newspapers (10.4%) formed sources of climate information. The farmers' adaptation strategies were modifying planting dates (77.1%), using drought-resistant varieties (86.5%), applying irrigation methods (54.2%), diversifying crops (97.9%), practising crop rotation (93.8%) and organic farming (98.9%). Probit regression analysis indicated that education ($P < 0.01$), household size ($P < 0.01$), farming experience ($P < 0.01$), access to early climate change information ($P < 0.01$), and extension contacts ($P < 0.1$) were favourable determinants. In conclusion, potato farmers faced several challenges including climate-related issues, pests and diseases, limited resources and credit access, soil quality and fertility problems, and market fluctuations. The study's originality stems from its research survey in linking climate information to potato production and advancing potato farmers' knowledge. The study recommended the implementation of educational programs that focus on climate change awareness, sustainable farming practices, and the use of climate-smart technologies and seeking early climate information and extension services in improving crop performance.

Keywords: Climate Change; Information; Potato Production; Household Farmers

1. Introduction

Climate change is a global concern and its repercussions are particularly critical for food security in developing nations such as Nigeria. It has been reported to threaten global agricultural systems, affecting food security, livelihoods, and environmental sustainability [1]. This is evident in the alterations to temperature, humidity, evaporation, precipitation, and water runoff patterns which negatively influence crop production. Increase in destructive weather outcomes such as dry spells, flood tide, hot-waves, violent storms and infernos have exacerbated crop production leading to low yields, crop losses, soil erosion, land degradation and reduced agricultural productivity [2]. Nigeria is already experiencing adverse consequences in changing weather conditions which is anticipated to deepen in coming decades. As Africa's largest economy and most populous country, Nigeria is highly vulnerable to climate change risks. Key climate projections for Nigeria include increasing temperature, changing rain forms, changing sea-depth, and other future occurrences. The highlighted shifts threaten crop production including potato crops. According to the latest FAO data, the world produces approximately 375 million tonnes of potatoes annually, with China and India being the top producers, producing around 95.5 million tonnes and 56 million tonnes, respectively; other major producers include Ukraine, the United States, Russia, Germany, and France [3]. Potato, being a staple crop in Nigeria, faces severe exposure to a changing climate, including erratic rainfall, temperature variations, droughts, and increased occurrences of pests and diseases. Nigeria is one of the largest potato producers in Africa and produces around 1.1 million metric tons of potatoes annually with the majority of the production coming from small-holder farmers. Potato farming holds significant economic and nutritional value for numerous households in Nigeria. It contains carbohydrates, fibre, protein, Vitamin C, and potassium and equally contributes to Nigeria's gross domestic product of agriculture. Various varieties of potatoes are produced in the coun-

try, which include Irish potatoes, white-fleshed sweet potatoes, and orange-fleshed sweet potatoes. Potato production in Nigeria predominantly occurs in small farms whose farmers still rely on traditional tools such as machetes and hoes as opposed to tractors. According to an earlier study, an estimated 300,000 households in Nigeria engage in potato production, which translates to an average planted area of 1 hectare (2.5 acres) per household each year [3]. However, with the exacerbation of climate change, farmers in the State are experiencing fluctuation in average weather conditions, increased weather uncertainties, reduced cropping seasons, decreased soil fertility, and reduced farm yield. Such changes have significant implications for food security in a country where hunger, malnutrition, and poverty are already prevalent.

In recent times, the mounting threats posed by climate change have jeopardised the sustainability of potato farming. Moreover, deficient understanding regarding the changing climate in potato cultivation has resulted in decreased yields, low outputs, post-harvest losses, increased pest and disease incidence, and reduced income and profitability of potato farming in Africa and Nigeria [3]. These have led to economic losses and compromised food security in African countries. However, several studies have addressed climate change influences on many crops in Nigeria such as cassava, maise, yam, sorghum, rice, etc. and extensively noting the devastating impacts of climate change on these identified crops [4–9], but interestingly, minimal studies have been done on tuber crops such as potatoes, hence creating a research gap in knowledge and literature and moreover, distinguishing this research from previous ones already established. The study noted climate change information as a very compelling tool for potato production in the study location. In addition, this study remains one of the newly studies to consider climate change information and potato production in Nigeria.

1.1. Theoretical, Empirical and Conceptual Framework

According to an empirical study by von-Gehren et al., climate change, particularly rising temperatures and altered precipitation patterns, poses significant threats to global potato production, potentially leading to yield reductions and impacting food security, especially in regions where potatoes are a staple food [10]. Elevated temperatures can cause heat stress in potato plants, leading to stunted growth and reduced tuber development. Warmer temperatures can accelerate leaf senescence (yellowing and dying) and impact tuber bulking, leading to significant yield declines [11]. Global warming may necessitate changes in planting times and the use of later-maturing potato varieties. Changes in precipitation patterns, including droughts and increased intensity of rainfall events, can lead to water stress, negatively impacting potato growth and yield. Increased irrigation requirements may be necessary to maintain potato production in regions experiencing reduced rainfall, which can be costly and unsustainable. Climate change can alter the distribution and populations of potato pests and diseases, leading to increased crop losses. Changes in temperature can affect the dynamics of vectors that transmit diseases, further exacerbating the problem. Another study by Rubí et al. reveals that at high latitudes, global warming may lead to changes in planting times, the use of later-maturing cultivars, and a shift in the location of potato production [12]. As the potato is a cool-season crop, heat can also be considered a limiting factor for potato production. Studies on the impact of a changing climate on potato production identified heat stress as a major factor affecting yield, as the potato tends to halt tuber development under heat stress [13]. A study survey by Parker et al. shows that climate change poses significant challenges to potato production, potentially leading to yield reductions, altered growing seasons, and increased vulnerability to extreme weather events, impacting both global and regional potato yields [14]. Potatoes thrive in temperate conditions, with optimal tuber growth occurring between 5-30°C. Global warming, predicted to increase temperatures by 1.1 to 6.4°C by 2100, can negatively impact potato production. Temperatures above 30°C can slow tuber growth, reduce starch partitioning,

cause physiological damage (such as brown spots), and shorten tuber dormancy, leading to premature sprouting. Consequently, Chilipa et al. stated that potato is one of the most vulnerable crops in changing climates, with events such as long-lasting droughts, extreme heat, and unanticipated frosts [15]. The temperature is expected to increase as the climate changes, with inconsistent precipitation patterns.

In Nigeria, with potato production facing risks from climate change, adaptation is very crucial to sustain yields and livelihoods. A review of current literature reveals diverse climate adaptation strategies employed by potato farmers worldwide [16–18]. Key tactics include adjusting agronomic practices, harnessing technology, adopting resilient cultivars, diversifying income, and leveraging indigenous knowledge. Most researchers emphasise that adaptation measures must be taken up to offset the negative impact of a changing climate, such as rising temperatures, increased occurrence of drought, and the emergence of new pests and pathogens, on agricultural production. Many different adaptation strategies have been proposed, in particular to reduce the impact of drought. These include the shifting and adjusting of planting dates to more favourable conditions, choosing better-adapted varieties, and better water management, such as implementing efficient irrigation measures, securing additional water supplies and improving soil moisture retention [19]. Studies show that a widespread adaptive response is altering planting and harvesting schedules to match shifting seasonal timings under climate change [20–22]. Precision technologies such as drip irrigation, rainwater harvesting, and targeted fertiliser application can buffer against rainfall variability and water stress. They consider strategies such as using heat and drought-resistant varieties, optimising planting dates, improving water management through irrigation and water harvesting, and implementing preventive plant protection measures. In addition, other studies emphasised to select potato varieties that are specifically bred or known to be tolerant to high temperatures and drought conditions, using early-maturing varieties to allow for more flexibility in planting and harvesting, potentially providing additional income if cultivated in between other crops, delaying planting to avoid the hottest and driest periods, or consider planting earlier to take advantage of cooler temperatures [23–25]. Ensure timely harvesting to prevent losses due to heat stress or disease. Implementing efficient irrigation systems to ensure adequate water supply, especially during dry periods, applying of mulch to retain soil moisture and reduce water loss. Improve soil health and water-holding capacity by adding organic matter through composting or cover cropping [26]. Use fertilisers efficiently to avoid nutrient runoff and ensure optimal plant growth. Engaging with local farmers and communities to share knowledge and promote adaptation strategies. Support research and development efforts to develop climate-resilient potato varieties and farming practices. Adaptation can also include behavioural shifts such as individuals using less water, farmers planting crops that are better suited to the changing climate, and more household farmers subscribing to flood insurance policies [27]. Adaptation can range from building flood defences, setting up early warning systems for cyclones, switching to drought-resistant crops, to redesigning communication systems, business operations and government policies. Climate adaptation protects people and places by making them less vulnerable to the impacts of climate change. For example, to protect against sea level rise and increased flooding, communities might build seawalls or relocate buildings to higher ground. Erecting good drainage systems that are safer and more sustainable. Replanting forests and restoring damaged ecosystems. Diversification of crops is needed so that they are better able to adapt to changing climates and investigate and develop innovative solutions to prevent and manage natural disasters [28].

In this context, integrating effective climate information services (CIS) becomes paramount. According to previous studies, CIS provides climate data and information to help individuals and organisations make informed decisions about climate variability and change, supporting adaptation and resilience [29–31]. CIS makes forecasts and projections that are crucial for decision-making and adaptation planning in agriculture

[9]. The accessibility of accurate climate information can significantly enhance farmers' productivity and resilience. Farmers in Nigeria, who primarily rely on rainfed agriculture, require climate information to manage climate risks effectively and make informed decisions in their farming practices [32]. CIS involves the collection, analysis, packaging, and distribution of climate data, including temperature, rainfall, wind, soil moisture, and ocean conditions, to specific users. CIS is crucial for supporting Africa's response to climate change, enabling individuals and organisations to anticipate and manage climate-related risks. It helps users understand the potential impacts of climate variability and change, allowing them to make better decisions in areas such as agriculture, water management, and disaster preparedness. It provides information about expected weather patterns over a season, helping farmers plan planting and harvesting activities. Climate services help bridge the gap between short-term weather events and long-term climate impacts [33]. In addition, CIS is a veritable tool in ensuring sustainable potato production and farmers' livelihoods. CIS fosters knowledge sharing and collaboration among farmers and stakeholders, promoting modern agro-technologies. Hence, addressing the synergy between climate change information and potato production in the state becomes a necessity in repositioning potato cultivation under adverse climatic impacts. This addresses the research hypothesis upon which the objectives of the study are focused in examining climate change information and potato production in Ebonyi State, Nigeria.

2. Materials and Methods

The project inquiry took place in Ebonyi State, Nigeria, situated in the southeast zone with a population of 3,242,500 persons. The State is known for its agricultural enterprise with over 55 percent of potato farmers. The State has 13 local government areas (LGAs). The totality of the cultivated land area is 5,533 km^2 with Latitude: 6°10′ 40.7028″ and Longitude: 7°57′ 33.4296″. A purposive method was used to select the potato farmers. This method was deployed specifically to target the potato household farmers in the study location and to select those farmers practising climate change adaptation strategies in the study location. At first, four LGAs known for intensive potato cultivation were picked from the 13 LGAs. Again, from the four selected LGAs, six communities were picked to make 24 communities. Consequently, with 24 communities sampled, four potato farmers were picked from a total of 96 farmers. The 96 potato farmers represented the total sample used for the study. The information concerning the potato growers was gathered from LGAs situated in the State. The research information was gathered with a questionnaire and was predicted using mean, frequency and percentage, charts and a probit regression model. The probit regression model predicted causal factors responsible for awareness in changing climate and adaptation tendencies of potato producers. The probit regression model is a scientific analytical tool used to model a dichotomous or binary or dummy dependent variable with more than one input variable. It has advantage over other analytical tools in that it produces clear results with good statistical degrees which are not spurious or erroneous. The dependent variable (which is consequent upon the probabilities of the individual potato farmers' choice of adaptation strategies used to mitigate climate change in the study location. The independent variables are the factors that significantly influenced the individual potato farmers' adaptation to climate change and their awareness capacity or levels. The research study hypothesis is expressed in the null form, which states that the independent parameters considered for the study do not have any significant influence or relationship with the individual potato farmer's adaptation capacity and awareness levels.

2.1. Expected Signs of Influence of Independent Variables

The independent variables considered for the study are noted in **Table 1**, describing their parameter

symbols, measurable quantities and expected signs.

Table 1. Expected Signs of Influence of Independent Variables.

Variable	Parameter Symbols	Measurable Quantities	Expected Signs
Age	X_1	Years	Negative
Education	X_2	Number of years spent in school	Positive
Household size	X_3	Number of persons	Positive
Farm income	X_4	Naira	Negative
Farm size	X_5	Hectares	Negative
Participation in climate change workshop	X_6	Number of times participated	Negative
Extension access	X_7	Number of visits	Positive
Farming experience	X_8	Number of years	Positive
Climate change information access	X_9	Accessed = 1, otherwise = 0	Positive
Experienced climate change events	X_{10}	Yes = 1, No = 0	Positive

The probit model structure is determined as follows:

$$Pi = Pr\,(Y = 1/X) = Pr\,(I_i \le I_i) = Pr\,(Z_i \le B/X_i) = F(BX_i) \quad (1)$$

$$F\,(I_i) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{BXi} e - z^{2/2}\, dz \quad (2)$$

Where:

Pi = Pr = {Probability of ith farmers' adaptation to climate change = 1 and otherwise = 0}

F = Standard normal cumulative distributed function

B = Coefficients

X_i= represents the independent variables such as:

X_1: Age (years)

X_2: Education (number of years spent in school)

X_3: Household size (number of persons)

X_4: Farm income (Naira)

X_5: Farm size (hectares)

X_6: Participation in climate change workshop (number of times participated)

X_7: Extension access (number of visits)

X_8: Farming experience (number of years)

X_9: Climate change information access (Accessed = 1, otherwise = 0)

X_{10}: Experienced climate change events (Yes = 1, No = 0)

3. Results

3.1. Socio-Economic Characteristics of Potato Growers

Table 2 shows the major socio-economic features of potato producers. The results of the study depict that the mean age of the potato farmers was 47 years. The potato farmers were mostly male, married, relatively educated and had a household size of 11 persons with 19 years of farming experience. The potato farmers are dual farmers who combine potato farming with other occupations, such as trading, artisan, etc. The potato farmers participated in agricultural workshops and training and had fewer extension contacts due to the paucity of extension agents in the study location. The farmers had small land holdings, and the majority of them do not belong to cooperative societies. Furthermore, the potato farmers used their personal savings to start their potato farming business, inherited their land holdings and deployed family labour to save costs.

Table 2. Socio-Economic Characteristics of Potato Growers.

Variable	Mean/Percentage
Age	47
Sex	
Male	46.9
Female	53.1
Marital status	
Single	21.9
Married	69.8
Widowed	8.3
Level of education	12
Household size	11
Farm Size	2
Extension contacts	1.4
Cooperative membership	
Yes	12.5
No	87.5
Participation in workshop/training	1.3
Farming Experience	19

Source: Field survey data, 2024.

3.2. Climate Change Awareness

Figure 1 presents the climate change awareness

of the potato growers. It shows the percentage and frequency distributions of the potato farmers in the study area, categorised as highly aware and not aware, respectively.

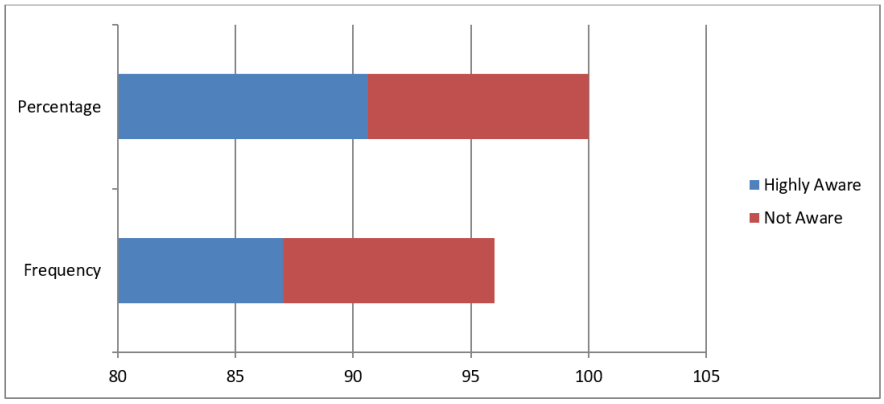

Figure 1. Climate Change Awareness.

3.3. Information Sources of Climate Change

Figure 2 demonstrates the information source of the changing climate. It shows the various sources or mediums of receiving information relating to climate change in the study area, including television, radio, newspapers, workshops/trainings, fellow farmers, the internet, and others.

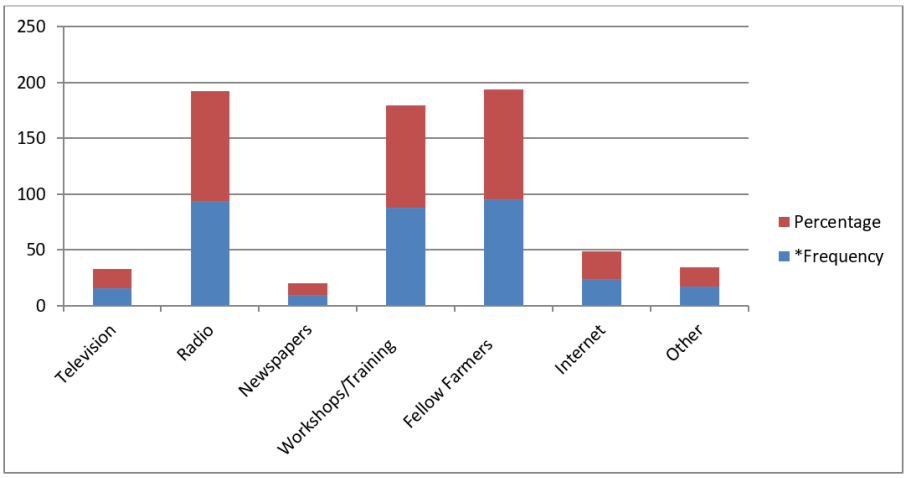

Figure 2. Information Source of Climate Change.

3.4. Climate Change Adaptation Strategies of Potato Growers

Table 3 presents related adaptation technologies deployed by potato farmers. The result shows that the potato farmers used varied adaptation strategies to mitigate the negative impacts of climate change in the study location. These various adaptation methods include modifying planting dates, using drought-resistant varieties, adopting irrigation methods, diversifying crops, introducing crop rotation, applying organic farming practices, implementing sustainable pest management, utilising advanced technology and machinery, and conducting regular soil testing and analysis.

Table 3. Climate Change Adaptation Strategies of Potato Growers.

Climate change adaptation strategies	*Frequency	Percentage
Modifying planting dates	74	77.1
Using drought-resistant varieties	83	86.5
Adopting irrigation methods	52	54.2
Diversifying crops	94	97.9
Introducing crop rotation	90	93.8
Applying organic farming practices	95	98.9
Implementing sustainable pest management	72	75.0
Utilising advanced technology and machinery	19	19.8
Conducting regular soil testing and analysis	14	14.6

Source: Field survey data, 2024. * Multiple Responses.

3.5. Determinants of Climate Change Awareness and Adaptation Strategies of Potato Farmers

Table 4 shows the causal factors responsible for awareness of changing weather conditions and the ameliorating techniques of potato farmers. The results indicate that the independent factors considered include age, education, household size, farm income, farming experience, farm size, seeking early climate change information, participation in climate change workshops, experiencing climate change outcomes, and extension contacts. These variables independently and significantly determined the awareness and adaptation capacity of the household potato farmers in the study location.

Table 4. Determinants of Climate Change Awareness and Adaptation Strategies of Potato Farmers.

Variables	Coefficients	t-Values	S.E
Constant	8.991	2.001**	4.493
Age	−7.910	–0.842	9.394
Education	8.532	3.351***	2.546
Household size	10.541	4.853***	2.172
Farm income	–0.999	–2.945**	0.513
Farming experience	7.331	3.321***	2.207
Farm size	–5.922	–0.923	6.416
Seeking early climate change information	0.789	3.321***	0.238
Participation in climate change workshops	–21.831	–1.063	20.537
Experienced climate change outcomes	0.954	2.042**	0.467
Extension contacts	8.431	2.777**	4.744
R2	0.896		
F-value	17.888		
N	96		

Source: Field survey data, 2024; Significant at *** 1% and ** 5% levels.

3.6. Perceived Challenges in Potato Farming

The results of the perceived challenges of potato farmers are laid out in **Table 5**. The results indicated that the potato farmers suffered various challenges ranging from climate-related challenges, pests and diseases, limited access to farming resources (seeds, fertilisers), limited access to credit, soil quality and fertility issues, market access and price fluctuations, labor shortages, post-harvest losses and storage problems, government policy issues, infrastructure and trans-

portation difficulties. These problems negatively influenced potato production in the study location.

Table 5. Perceived Challenges in Potato Farming.

Perceived Challenges	*Frequency	Percentage
Climate-related challenges	84	87.5
Pests and diseases	91	94.8
Limited access to farming resources (seeds, fertilisers)	95	98.9
Limited access to credit	90	93.8
Soil quality and fertility issues	88	91.7
Market access and price fluctuations	67	69.8
Labor shortages	81	84.4
Post-harvest losses and storage problems	70	72.9
Government policy issues	68	70.8
Infrastructure and transportation difficulties	52	54.2
Others	11	11.5

Source: Field survey data, 2024; * Multiple Responses.

4. Discussion

In **Table 2**, the average age of potato growers is 47 years. This demonstrates the activity and youthfulness of potato growers, which is favourable for agricultural activities. However, it also indicates that there is a need for succession planning and youth involvement in potato farming, as the current farmers are likely to retire in the near future [34]. Among the surveyed farmers, 46.9% are male, while 53.1% are female. This shows that women play a significant role in potato production in the state, as they constitute more than half of the farmers. This is consistent with the general trend of women's participation in agriculture in Nigeria, where they account for about 60% of the agricultural labour force. The majority of farmers 69.8% reported being married, while 21.9% were single. The greater percentage of married people indicates that most of the farmers have stable family structures and social support, which may enhance their productivity and income. Married farmers may also benefit from the division of labour and cooperation between spouses in potato farming activities. The data shows that average education of the farmers is 12 years. This connotes that most farmers attained secondary schooling which is likely to enhance their ability in potato farming. Education influences the practice of modified varieties, fertiliser application, pest and disease control, and post-harvest handling [35]. The average size of members was 11. This shows that the farmers have large families, which may provide a cheap source of labour for potato farming. However, it may also imply a high dependency ratio and a high demand for food and other basic needs, which may reduce the disposable income and savings of the farmers. The farmers had an average land size of 2ha. This shows that the farmers operate on relatively small farms, which may limit their scale of production and income from potato farming. Small farm size may also constrain the use of modified technologies including mechanisation, irrigation, and crop rotation [36]. The average number of extension visits was 1.4. This depicts low access to extension services, which may affect their access to information and knowledge on improved technologies and practices in potato farming. Extension contacts may also facilitate the linkages in the potato chain value, such as input suppliers, processors, and marketers. Only 12.5% of potato producers are cooperative allies, while the majority 87.5% was not members of a cooperative. This indicates that the minority may have accessed their farming inputs through cooperative societies to which they belong. Cooperative membership provides benefits such as access to credit, inputs, markets, and training [37]. The average number of participations in agricultural workshops and trainings was 1.3.This implies that the farmers have some exposure viaworkshops/training, which may enhance

their capacity and skills in potato farming. Workshops/training may also provide opportunities for learning from experts and peers, and for networking and collaboration with other stakeholders in the potato value chain. The average number of farming experience was 19 years. This indicates that potato growers have considerable experience in potato cultivation. Farming experience may also influence the farmers' attitude and behaviour towards new technologies and practices, as well as their risk perception and management [38]

In **Figure 1**, according to the field survey, most potato growers 90.6% had high awareness of climate change. This means that they understand climate change and its influence on their potato farming. On the other hand, a few farmers, 9.4%, had low awareness of climate change. This means that they had no knowledge of climate change or its impact on their farming. This could be attributed to poor exposure and illiteracy [39].

In **Figure 2**, according to the study, a good number of the farmers, 97.9%, sourced climate change information via radio. Radio is important in disseminating information on climate change. It is mostly effective, since it has a wider coverage and reaches a large population. Workshops and training sessions were also important sources of information with 91.7% of potato farmers implying that they accessed climate change information by participating in climate change workshops and training. Workshops and training expose farmers to new and recent information, especially in this climate change era. Fellow farmers were another important source of information, with 98.9% of the potato farmers implying that they learnt about climate change from their fellow farmers. This shows that farmers have strong social networks and share their knowledge and experiences with each other [40]. Other sources of information that the farmers mentioned were television, 16.7%, newspapers, 10.4%, the internet, 25.0%, and other sources, 17.7%. This could further imply that the farmers accessed climate change information through various means/channels available to them. This could also assist in pursuing effective adaptation and mitigation practices.

In **Table 3**, according to the result, a range of adaptation schemes were adapted by potato producers. Modifying of planting dates was adopted by 77.1% of the potato farmers, indicating that they adjusted their planting schedules in response to changing climatic conditions. This adaptive measure allows farmers to align their planting with favourable weather patterns, optimising crop growth and yield [41]. Using drought-resistant varieties was another prevalent adaptation strategy among potato farmers, with 86.5% adopting this approach. By choosing varieties that are more resilient to drought, farmers can mitigate the negative impacts of water scarcity and ensure better crop performance under challenging climatic conditions. Adopting irrigation methods was adopted by 54.2% of the respondents. This strategy enables farmers to supplement rainfall and provide adequate moisture to their potato crops, reducing vulnerability to drought and water stress. Diversifying crops was widely employed adaptation strategy with 97.9% of the farmers, indicating that they engage in crop diversification. Practicing diversity of crops can spread their risks and enhance resilience to climate-related uncertainties. Diversification also offers the potential for alternative income sources and nutrient management. Introducing crop rotation was adopted by 93.8% of the farmers. Rotating cops limits the spread of potato pests and enhances yield resilience [42]. This strategy is particularly valuable in adapting to changing climate conditions. Applying organic farming practices was adopted by 98.9% of the potato farmers. Organic farming enriches the soil with adequate nutrients and suppresses soil acidity. By adopting organic practices, farmers can improve the resilience of their potato crops to climate change impacts while promoting environmental sustainability. Implementing sustainable pest management strategies was adopted by 75.0%. Sustainable pest management involves using integrated pest management (IPM) approaches that combine the best pest methods to reduce reliance on chemical pesticides. This strategy promotes natural pest control mechanisms and reduces the risks associated with pesticide use. Utilising advanced technology and machinery was adopted by a smaller

proportion of the farmers 19.8% employing this adaptation strategy. Advanced technology and machinery, such as precision agriculture tools and automated irrigation systems, can help optimise resource use, improve efficiency, and enhance climate resilience in potato farming. Conducting regular soil testing and analysis was adopted by 14.6% of the potato farmers. By regularly testing and analysing soil properties, farmers can make informed decisions regarding nutrient management, soil amendment, and crop selection, thereby optimising potato growth and yield [43].

In **Table 4**, the Education coefficient was beneficial and favourable at 1%. This indicates that higher levels of education make potato growers acquainted with environmental changes and control measures. Educated growers access information early enough compared to uneducated ones. Household size was beneficial and favourable at 1%. This connotes that larger households respond to environmental changes and their adjustment methods. Farmers from larger households have more labour resources, social networking, and knowledge-sharing opportunities. This enhances climate change awareness and utilisation of cheap labour in practicing climate change adaptation strategies. Farming experience became beneficial and favourable at 1%. This indicates experienced potato producers are more conscious of changes in weather and their adaptive procedures [40]. Farmers with more experience have likely encountered various climate-related challenges in the past, developing a deeper understanding of thematic changes and better techniques for adaptation. Seeking early climate change information became beneficial and favourable at 1%. Seeking early climate change information exposes farmers to shifts in climate and techniques for adaptation. Farmers who proactively seek information on weather disruptions tend to know more about their impacts and adopt appropriate adaptation measures in a timely manner. Experienced climate change outcomes became beneficial and favourable at a 5% level. This suggests that farmers who have personally experienced climate change outcomes are more exposed and better adapted to its impending consequences [44]. Furthermore, Extension contacts showed beneficial and favourable at 5%. This implies that an increase in extension services expands knowledge in changing environments and positions the growers to contend with it. Extension services expose farmers to climate-related issues and challenges, thereby increasing awareness and adoption of adaptation strategies to reduce their negative impacts on crop production. However, farm income was unfavourable and important at the 5% level. This could mean that low farm income generated from potato farming hinders the effectiveness of potato growers in contending with weather issues [45]. It should be noted that most environmental mitigation methods are capital-intensive and therefore require high capital for farmers to effectively adopt such practices.

In **Table 5**, findings specified that potato producers faced various challenges that impede potato production. About 87.5% of potato farmers identified climate-related challenges as a major constraint. Climate-related challenges include irregular rainfall patterns, droughts, floods, heat waves, and other extreme weather events [45]. These challenges negatively impact potato growth, yield, and overall farm productivity. Another significant challenge reported by potato farmers is pests and diseases, with 94.8% indicating their prevalence. Pests of potato, such as nematodes, aphids, etc., lower potato yield. The majority, 98.9% of the respondents, reported limited access to farming resources such as seeds, fertilisers, and other inputs. Insufficient availability and affordability of quality inputs can hinder optimal potato production and limit farmers' ability to adopt improved farming practices. Also, paucity of funds credit represented 93.8% of the growers. Limited funds restrict investments in appropriate technologies, purchase inputs, and expand their farming operations, thereby limiting their productivity and profitability. About 91.7% reported soil quality and fertility issues as a challenge. Soil degradation, nutrient depletion, and soil erosion can reduce the productivity of potato crops and necessitate additional investments in soil management practices. About 67.8% identified market access and price fluctuations as challenges. Difficulties in accessing markets, inadequate storage facilities, and

price volatility can affect farmers' profitability and income stability [32]. Labour shortages were reported as a challenge by 84.4% of the respondents. Difficulty in finding and hiring skilled labour during critical farming operations can hinder timely and efficient cultivation, harvesting, and post-harvest activities. About 72.9% of potato farmers reported post-harvest losses and storage problems. Inadequate storage facilities, improper handling practices, and lack of post-harvest management knowledge can lead to significant losses and reduced marketability of the harvested potatoes. Government policy issues were identified as a challenge by 70.8% of the respondents. Inconsistent policies and inadequate support programs impede potato production. Infrastructure and transportation difficulties were reported as challenges by 54.2% of the respondents. Inadequate road networks, lack of transportation facilities, and poor market infrastructure can impede the timely movement of inputs and harvested produce, affecting the overall efficiency of potato farming [46].

5. Conclusions and Recommendations

The research outcomes depict a greater percentage of the potato growers noticed shifts in climate and employed multiple adaptation strategies in mitigating the adverse effects on potato production in the state. Social-economic parameters such as education, household size, farm income, farming experience and extension visits appeared as major determining factors of shifts in climate and mitigation strategies of potato growers. It is believed that government and policymakers will find this study to be a road map in developing policies to enhance sustainable potato yield consequent on these recommendations:

a) Enhance Educational Programs: The government should develop and implement educational programs that focus on climate change awareness, sustainable farming practices, and the use of climate-smart technologies. These programs should target both current and aspiring potato farmers, providing them with the knowledge and skills necessary to adapt to climate change.

b) Improve Access to Information and Extension Services: The government should strengthen information dissemination channels and extension services for potato farmers. This can be done through the use of mobile technology, farmer field schools, and regular workshops or training sessions. Providing timely and accurate information on climate change trends, best practices, and available support services can empower farmers to make informed decisions and adopt appropriate adaptation strategies.

c) Facilitate Access to Financial Resources: The government should establish mechanisms to improve access to credit and financial resources for potato farmers. This can include promoting initiatives that provide affordable loans, grants, or subsidies to potato farmers.

d) Strengthen Pest and Disease Management Strategies: The government should address the challenges related to pests and diseases by promoting integrated pest management approaches. This can involve training farmers on pest identification and monitoring, promoting the use of resistant varieties, encouraging crop rotation, and implementing sustainable pest control measures.

e) Improve Market Access and Stability: The government should support the development of efficient and reliable market channels for potato farmers. This can be achieved through the establishment of farmer cooperatives, improvement of transportation and storage infrastructure, and the facilitation of market linkages with processors, retailers, and export markets. Ensuring fair prices, reducing post-harvest losses, and promoting value addition can enhance the economic viability of potato farming and incentivise climate change adaptation.

f) Strengthen Policy Support: The government should develop and implement policies that prioritise climate change adaptation in agriculture. This can involve integrating climate change considerations into agricultural development plans, providing incentives for the adoption of climate-smart practices, and creating an enabling policy environment that supports sus-

tainable potato farming.

g) Foster Collaboration and Knowledge Sharing: Stakeholders in agriculture should encourage collaboration among farmers, researchers, extension agents, etc., to facilitate the exchange of knowledge and experiences. This can be achieved through the establishment of farmer networks, demonstration farms, and platforms for sharing best practices and lessons learned. Encouraging dialogue and collaboration can accelerate the adoption of climate change adaptation strategies and foster innovation in potato farming.

Author Contributions

Conceptualization, E.E.O., I.I.U., M.N.O. and I.U.O.N.; methodology, G.N.B.-C., E.R.K., C.O.C.; software, E.U.N.u., C.O.S.; validation, K.T.E., O.I. and E.E.O.; formal analysis, P.A.O., B.N.A.; investigation, R.A.A., C.A.P.-O.; resources, I.E.M.-N., E.E.I.; data curation, E.E.O., I.I.U.; writing—original draft preparation, E.E.O., C.A.N., G.N.B.-C.; writing—review and editing, E.E.O., B.N.A.; visualization, M.N.O., I.U.O.N.; supervision, E.E.O., I.U.O.N.; project administration, R.A.A., E.E.I. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The study made use of primary data which is available upon reasonable request.

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Conflict of Interest

The authors declare that no conflict of interest exists.

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